933

ELECTRICITY
AND
MAGNETISM

PREPARED IN THE OFFICE OF
THE DIRECTOR OF AIR SERVICE

AUGUST, 1919

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

WAR DEPARTMENT

Document No. 933

Office of The Adjutant General.

WAR DEPARTMENT,
WASHINGTON, *August 4, 1919.*

The following publication, entitled "Electricity and Magnetism," is published for the information and guidance of all concerned.

[062.11, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

PEYTON C. MARCH,
General, Chief of Staff.

OFFICIAL:

P. C. HARRIS,
The Adjutant General.

CONTENTS.

	Page.
Elementary electricity:	
Elementary principles	7
The electric circuit	7
Conversion of energy	7
The factors of a current	7
Water current factors	8
The current volume	8
The current pressure	8
The resistance	8
Use of factors	8
Resistance	8
Electrical volume, pressure and resistance	8
Electrical current volume	8
Electrical current pressure	9
Electrical current resistance	9
Relation of electrical units	9
The electric circuit	9
Circuit terms	9
Kinds of circuits	9
Terms applied to circuits	10
Open circuit	10
Closed circuit	10
Live circuit	10
Dead circuit	10
The electric current	10
Pressure and current flow	10
Classification of currents	10
Direct current	10
Continuous direct current	10
Pulsating direct current	10
Alternating current	10
Source of E. M. F	11
Conductors and nonconductors	11
Resistance and length	11
Resistance and cross section	11
The effect of resistance upon a circuit	11
Electricity not generated	12
Causes of resistance in circuits	12
Magnetism:	
Natural magnets	12
Definition of a magnet	13
The permanent magnets	13
Different magnetic characteristics of iron and steel	13
To make an artificial magnet	14
Magnetizing each half separately	14
Magnetization by divided stroke	14
Magnetization by an electric current	14
Magnetization by an electromagnet	15

Magnetism—Continued. Page.
Magnetic force 15
The nature of magnetism 15
Experimental proof of the molecular theory of magnetism 16
Breaking a magnet 16
Magnetic saturation 17
The weakening of permanent magnets 17
Keepers 17
The poles of a magnet 17
The poles 18
Magnetic attraction and repulsion 18
The magnetic field 18
The electromagnetic field 19
Action of lines of force 19
An iron core and a winding 19
Field intensity of a core 20
The principle of induction 20
Experiments in induction 21
The polarity of the armature core as it rotates 22
The path of lines of force through the core 22
The reversal of core flux 22
Polarity changes per revolution 24
Armature core and windings 24
The primary winding 24
The secondary winding 24
Primary E. M. F 24
Secondary E. M. F 25
Primary and secondary alterations 25
The shuttle armature 25
The Dixie armature 26
Principle of the Dixie 26
The special case of the S. E. V. Bosch 27
Magneto breaker boxes 27
Breaker box construction 28
Advance and retard 29
The Dixie breaker box 29
Some of the common troubles of the breaker box 29
Excessive oil 30
Seizing of the breaker arm fulcrum pin bushing 30
Dirty platinum contact points 30
Pitted platinum points 31
Note proper setting of platinum points 31
Worn cam blocks or cam rises 31
Weak springs 31
Breaker assembly disk loose 32
Control rods to control lever not correctly adjusted 32
Improperly washing breaker box parts with gasoline 32
The condenser 32
Condenser construction 33
Charging a condenser 33
Functions of the condenser 34
The high-tension distributor 34
The complete secondary circuit 34
The primary circuit outside the magneto 35

ELECTRICITY AND MAGNETISM.

THE MAGNETO.

ELEMENTARY ELECTRICITY.

Elementary Principles.—The exact nature of electricity is as yet unknown although many theories have been put forth. We do know that it is a form of energy which may be controlled and readily converted into mechanical heat or chemical energy. As electrical energy it may be transferred along definite paths from one point to another in a length of time which is almost negligible. The flow of electricity follows definite laws, so that its application to industry is an exact science, enabling the engineer to forecast results with better success than with any other form of energy.

The Electric Circuit.—To perform work, electricity must be in motion, just the same as mechanical forces, and motion of electricity is secured only when a closed circuit is provided over which it may travel. The circuit may include motors, generators, lamps, heating devices, wires, etc., and under certain conditions an air gap. But in all cases the path leading from the source of energy must be completed by a return path.

Conversion of Energy.—Energy in any form whatsoever can not be destroyed but only converted from one form to another. When electricity is made to drive a motor it is converted into mechanical energy. When it is made to charge a storage battery it is converted into chemical energy, and when made to heat an iron it is converted into heat energy.

The Factors of a Current.—Its everyday use makes the word "current" a very general word. It imparts uncertain facts, that is, undefinied facts. For example, one may speak of a "current of water," and in so doing must preface the expression with some qualifying word, such as large, small, muddy, strong, weak, little, etc. It can be readily understood, then, that when the electrical engineer takes command of the situation, the undefined facts must be replaced with very clearly defined facts that we shall call "Factors of the current." These factors must tell just what kind of current is being dealt with. Let us take first the case of the water current and apply the main factors.

WATER CURRENT FACTORS.—It is common practice to give these factors for the water current:

The current volume.—The rate of flow in cubic feet per minute, or gallons per hour. Any volume measure divided by the time of flow. Volume must be known in order that the conductor or pipe may be made the correct size to deliver the quantity finally desired.

The current pressure.—The water head or difference of level in feet. Difference of pressure in pounds per square inch. Pressure must be known in order that the conductor be made strong enough or that the correct rapidity of flow be established.

The resistance.—An opposition due to unevenness of pipes, size of apertures, etc., increasing with length of pipe, with contractions, roughness, etc. Resistance decreases with the increase of sectional area. Resistance must be known as it directly controls the rate of flow.

USE OF FACTORS.—These are the factors, then, that we say govern the current. By manipulation of the factors we are fully able to control a current. Thus, we may bring a current to "rest" just by making the resistance greater than or equal to the propelling force, the pressure. A flowing current, "a current of motion," is being propelled by a force greater than the total line resistance.

RESISTANCE.—As soon as motion is imparted to a current, resistance appears. In fact, as far as we know, resistance always appears wherever motion takes place. It is, therefore, properly termed the natural opposition to the propelling force of the current. The student must not look upon resistance as an evil in all cases which opposes current flow, but must stop to realize that resistance is quite frequently added to control the flow, shut it down, lessen it, or govern it. Its addition to the line of flow increases the pressure.

ELECTRICAL VOLUME, PRESSURE AND RESISTANCE.—Exactly what electricity is we do not know; indeed we are in much the same situation as the ancient who utilized a water current to operate a water wheel but who did not concern himself with the chemistry of water. He did not know what water was, but he knew what he could do in a useful way with it. That is our present concern with electricity; we know a great deal about it, what uses we can make of it, its main performances, etc., but we do not know what it is. The electrical engineer with the common actions of water currents in his mind, has found it most convenient to compare water current performances to those of electricity; in consequence, therefore, speaks of a "current of electricity." With this idea in view, we might for simplicity compare the current factors in each case.

ELECTRICAL CURRENT VOLUME.—As with the water current, volume is based on the rate of flow. The rate of flow being expressed

by a unit term called the "ampere." This unit expresses the rate of flow within itself and it is not correct to speak of it as a measuring quantity, such as comparatively, the gallon, but its equivalent to "gallons per second or minute."

ELECTRICAL CURRENT PRESSURE.—The propelling force of a water current is measured in pounds per square inch. The propelling force of an electrical current is measured by a unit called the "volt." The propelling force itself is called the "electricity moving force," or for short, the "electro motive force," commonly abbreviated, "E. M. F." The E. M. F. of a current is thus said to be so many volts or of such a voltage.

ELECTRICAL CURRENT RESISTANCE.—Just as the water pipe offers a resistance to the water flow, so does every conductor offer resistance to the flow of electricity. The opposition is called "resistance," abbreviated "R." In order to compare the resistance of different materials some standard unit of resistance had to be agreed upon. This unit is called the "ohm."

RELATION OF ELECTRICAL UNITS.—The three electrical units are so selected and legalized that an electrical pressure of 1 volt will force a current of 1 ampere through the resistance of 1 ohm.

THE ELECTRIC CIRCUIT.—As the common definition of the word "circuit" implies, it is a pathway circular or nearly so in form that leads directly back to its starting point. Electrically speaking, however, it may have no semblance to a circle whatever; it is the path covered by an electric current in its passage through a conductor from its starting point back again. When a wire leaves a battery pole, passes through a loop and back to the opposite pole of the same battery, we have a circuit in its simplest form. A circuit may be hard to trace on account of the changing nature of its conductor, thus, the conductor of the circuit may start as a wire cable, include pieces of apparatus and different pieces of machinery, finally finishing as a cable again.

CIRCUIT TERMS.—The habit of referring to circuits as "lines" has grown so that the two words are almost interchangeable. For instance, we may have a circuit where a conductor leaves the battery, passes to a piece of apparatus, and returns to the battery again. That part of the circuit from battery to apparatus is called the "positive line," while that part from the apparatus back to the battery again is called the "negative line."

KINDS OF CIRCUITS.—The word "circuit" is used in connection with many other words which express the general type of circuit, or express the type of current the circuit is intended to carry, for example; series circuit, parallel circuit, short circuit, D. C. circuit, A. C. circuit, etc.

Terms Applied to Circuits.—Many electrical slang terms have been applied to the circuit, some of which have become more or less standard in nature, a few appear below.

Open circuit: A circuit that has been broken; one with an open switch; some circuit with a misconnection so that its conductor is not continuous.

Closed circuit: A completed circuit; one where the conductor is complete to the extent that the circuit does not offer other than the intended resistance.

Live circuit: A circuit through whose conductor a current is flowing.

Dead circuit: A circuit through whose conductor no current is flowing.

The Electric Current.—In hydraulic, pneumatic, or steam engineering, the indications of the pressure gauge are of the utmost importance to the engineer. In fact he is always considering and asking about the pressure. He does not trouble himself about the water, air, or steam, for none of these would be of any use to him unless they existed under pressure. It is simply the pressure under which they exist that gives them their working power. In a like way the electrical engineer is concerned about the electrical pressure; he does not think or talk about the electricity. But the pressure at which the current is being propelled is always in his mind as being of the first importance.

Pressure and Current Flow.—No current can possibly flow unless there is a difference of electrical pressure in the circuit, and if the current is to be made to "work," the pressure must be great enough for the necessities at hand. By setting the pressure idea foremost, it is customary to define a current thus: That agency which comes into action when an E. M. F. is applied to a closed electric circuit.

Classification of Currents.—Electric currents are classified broadly as direct and alternating. A direct current is one which flows in only one direction. A continuous direct current flows at a uniform rate in one direction only. A pulsating direct current flows at a variable rate but always in the same direction. An alternating current is one which flows first in one direction and then in the opposite. In practice, alternating current is one which begins at zero value, increases to a maximum, decreases to zero, then increases to a maximum value in the opposite direction and again decreases to zero. This cycle is repeated periodically so many times per second. Thus we have 25 cycle current, 60 cycle current, etc.

An alternating current may be of regular frequency corresponding to a continuous direct current or interrupted as generated by a magneto with breaker points.

SOURCE OF E. M. F.—For simple work an E. M. F. is commonly obtained by the introduction into circuit of dry cells or storage batteries, or in the case of greater work, a mechanical force is applied to a magneto or generator.

CONDUCTORS AND NONCONDUCTORS.—The resistance varies with the nature of the material. Most of the metals are conductors, while silk, cotton, porcelain, shellac, oils, mica, paraffin, and dry air are such poor conductors that we call them "insulators." The well-known metals are named in the order of their conductivity—silver, copper, gold, platinum, tin, lead, etc. It will be noted that the first cheap practical metal for a conductor is copper.

RESISTANCE AND LENGTH.—If we take a piece of wire having a known resistance, say 20 ohms, and cut it in two equal lengths, we find upon checking up that each piece has just half the resistance of the former piece, or 10 ohms. Hence, the rule for resistance is: Twice the length, twice the resistance; or, the resistance of a wire of uniform section is proportional to its length.

RESISTANCE AND CROSS SECTION.—Resistance also depends upon the cross section of the conductor. The smaller the section, the greater the resistance; or, the resistance of a wire of uniform section is proportional to its length.

THE EFFECT OF RESISTANCE UPON A CIRCUIT.—When resistance is added to a circuit the immediate effect is of a double nature; the current flow is decreased and the pressure increased. This means a fall of amperage and a rise of voltage. This increase of voltage, of course, can not exceed the maximum voltage of the current source. It is hard to pick a simple example to illustrate this exact action as it occurs electrically. The nearest we can approach it is to take a water pipe and pump circuit as diagrammed in figure 1. Suppose a water pipe circuit is arranged and filled with water, as the circuit A, B, C, D. Situated on this circuit the pump P. A mechanic motive force applied to the pump will produce a "water motive force" which will start a current about the circuit. This circuit is also fitted with a valve V. The circuit itself will offer a certain amount of resistance to the flow of the current. This resistance will be overcome by the difference in pressure between pump inlet and outlet. The outlet represents a forcing-out pressure, "a positive pressure," the inlet, a sucking-in pressure, "a negative pressure." The negative pressure will be as much below the zero as the positive pressure is above it. Now, by partially closing the valve V, resistance is added, the current flow lessens; less water passes around the circuit per minute. But the pump keeps turning at the same speed and in consequence builds up a greater pressure.

Thus the rule for resistance is: Higher resistance gives greater voltage and less amperage.

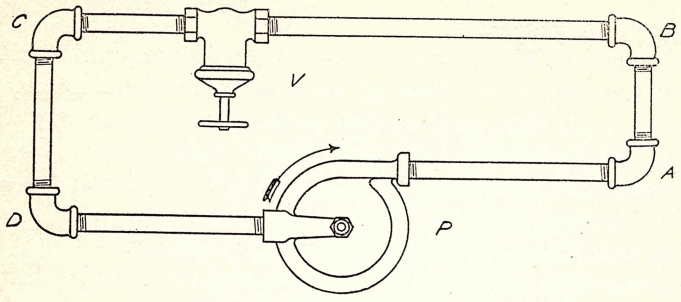


FIG. 1.

ELECTRICITY NOT GENERATED.—It is interesting to make note of this particular of the above case: That when the water current was started, the water was not generated. The water which was already there was merely set in motion, and this was done by a difference of pressure being created by the pump. In the same way we do not "generate" electricity. The electricity is already there and we set it in motion. Though the word "generate" is frequently used in connection with electric currents, it is merely an inheritance of an earlier period.

CAUSES OF RESISTANCE IN CIRCUITS.—There are many ways to add resistance to a circuit, some of which may be given as follows:

Decrease the size of the conductor.
Increase the length of the conductor.
Change the conductor to one of metal of higher resistance.
Introducing into circuit any piece of apparatus known to have much resistance.
Making poor contacts between the conductors of a circuit.
Introducing into circuit resistance coils. A type of coil formed of special high-resistance wire.
Wiring a lamp into the circuit.
Introducing any inductive coil into circuit, such as electromagnet winding.

It does not matter where the added resistance is introduced in the circuit; it has its effect on the entire circuit. If, therefore, a resistance coil is placed ahead of a piece of apparatus in the circuit, it will have the same effect as though it had been behind the apparatus.

MAGNETISM.

NATURAL MAGNETS.—The name "magnet" was first applied by the ancients to brown-colored stones, known as "magnetic oxide of iron" ($Fe3O_4$), because these as taken from the earth possessed the peculiar property of attracting small pieces of iron or steel. Later the Chinese discovered that if a piece of the ore were freely sus-

pended by a string it possessed the important property of pointing always in a particular direction, nearly north and south; hence they gave it the name of "lodestone" (meaning leading stone), and used it in this manner to navigate their ships. In studying the magnetic attractive force of a piece of lodestone by means of iron filings, it will be found that the attraction for the filings seems to be centered at two or more points on the stone, while at other points no filings are attracted.

Definition of a Magnet.—A magnet is a piece of steel, or other magnetized substance, which possesses the properties of attracting other pieces of steel or iron, or magnetizable bodies to it and of pointing, when freely suspended in a horizontal position, toward the North Pole of the earth.

The Permanent Magnets.—A permanent magnet is a hardened steel magnet possessing to a high degree the ability to retain its magnetic properties for some length of time. Some qualities of steel which possess good machine-tool properties are not adapted to making good permanent magnets. Steel containing a certain percentage of manganese can not be magnetized, while some brands of cast steel, spring steel, and mild plate steel are readily magnetized, but do not retain their magnetism permanently. Jessop's steel is well adapted to making good permanent magnets. Select a piece of good close grained rolled steel that has not been heated since it was made. Temper the steel glass hard by heating it to a moderately bright red temperature and then plunging it edgewise into water or oil. It will become very brittle and can be magnetized by any of the methods hereafter given. A permanent magnet will have its strength materially weakened if subjected to shocks or blows, a high temperature, or brought carelessly into contact with the poles of other strong magnets.

The simplest form of a permanent magnet and also the one with which people are more familiar is the compass needle. This needle is merely a bit of magnetized hardened steel and has the property of pointing toward the North Pole with one of its ends and, of course, toward the south with the other.

Different Magnetic Characteristics of Iron and Steel.—We have called attention to the compass needle being made of steel for the reason that steel differs from iron. Steel, especially hard, dense steel, has the ability to retain for long periods any magnetism imparted to it. Iron, on the other hand, especially if it is annealed and soft, will lose its magnetism practically the instant the magnetizing force is removed. Steel is always more dense in structure than iron. The ability to retain magnetism, therefore, depends upon hardness and density which iron itself may possess unless it is a very malleable type carefully annealed.

To Make an Artificial Magnet.—Secure a piece of hard-tempered steel (about 6 by ½ by ¼ inch) and mark one end with a file, which will be the N pole. Place the steel on a table and, beginning at the unmarked end of the steel bar, stroke its entire length with the south end of a strong artificial magnet. Lift the magnet clear at the end and return again for a second stroke in the same direction. Stroke it about 10 times in this manner and then repeat a similar stroking process on the other three sides of the bar. Plunge the newly made steel magnet into filings or small tacks, and note the distribution of magnetism. Suspend it horizontally in the stirrup and observe whether the marked end points toward the north when it comes to rest. Note that the N pole in the magnet you have made was always touched last by the S pole of the magnetizing magnet. One pole always induces the opposite pole in any magnetizable body at the point which was touched last by the S pole of the magnet. One pole always induces the opposite pole in any magnetizable body at the point where the pole last leaves that body.

Magnetizing Each Half Separately.—A better magnet will be obtained by magnetizing each half separately. Stroke one-half of the steel bar with the S pole, beginning at the center and following the same direction. Repeat this a number of times on each side; then using the N pole, stroke the other half in the same way. A horseshoe shaped magnet can be used to magnetize another piece of steel by stroking in the same direction. In stroking the opposite side, the same limb of the horseshoe must be brought into contact with the same pole, as before. A piece of soft iron laid across the ends of the horseshoe while being magnetized will give better results.

Magnetization by Divided Stroke.—Place the steel bar to be magnetized on two other bar magnets. Take two additional magnets, one in each hand, with the polarities indicated, and proceeding from the center, with unlike poles, stroke toward the ends in the same direction. Turn the bar over and repeat the operation about 10 times on each side.

Magnetization by an Electric Current.—If a number of turns of insulated wire be wrapped around the steel bar to be magnetized, and a strong current of electricity passed through the coil from a battery or dynamo, the steel will be permanently magnetized with an N and S pole after the current is turned off. Tapping the end of the steel with a hammer, while it is under the influence of the current, will produce better results. Instead of winding the wire around the bar, the bar can be inserted in a spool containing many turns of insulated wire when a stronger magnet will be obtained. In making a horseshoe magnet by this method, insert one limb all the way in the spool; turn on the curent; tap it; turn off the current; remove this limb and insert the other limb in the opposite end of the coil and

repeat the operations. You will now have a magnet, the strength of which, until the saturation point of the steel is reached, will depend on the current strength and the number of turns of wire on the spool.

MAGNETIZATION BY AN ELECTROMAGNET.—A bar electromagnet (i. e., the above spool and its iron core) may be substituted for the permanent steel magnets used in the previous methods for making a magnet, or two bar electromagnets connected by a piece of soft iron forming a horseshoe electromagnet may be used. In this case the current is passed through one spool in one direction, and then through the other spool in the opposite direction, when the free ends of the core will have an N and S pole. One-half of the bar to be magnetized can now be stroked over one pole, beginning at its middle point and following the same direction; stroke on all sides, and then stroke the other half of the bar on the other pole.

MAGNETIC FORCE.—The force exerted by one magnet on another to attract or repel it, or to attract iron filings, or pieces of iron, is termed "magnetic force." It is not perceptible to any of the senses. When the magnet has been plunged into filings, the space thus occupied is shown to be permeated with the force, and the filings serve as a useful indicator to show the nature of the force and its direction and distribution in the space surrounding the magnet. The magnetic force is not the same at all distances, but decreases as the distance from the magnet increases. The attractive force between a magnet and a piece of soft iron is mutual; that is, the iron attracts the magnet just as much as the magnet attracts the iron. This may be illustrated by suspending a piece of iron in a stirrup and noting the distance at which it is attracted by a magnet, and then suspending the magnet and permitting the iron to occupy the previous position of the magnet; or the magnet may be floated on a cork in a jar of water, and it will be equally attracted by the piece of iron.

THE NATURE OF MAGNETISM.—What is known as the "molecular theory of magnetism" is offered as an explanation of the phenomenon arising from the magnetism of a piece of steel or iron. The theory, which is beautifully illustrated by the experiments following, assumes that in a bar of steel, each of all the individual particles, or molecules which compose it, is a magnet. If the steel or iron is unmagnetized, then the particles arrange themselves promiscuously in the steel, but according to the law of attraction between unlike poles, the magnetic circuits are satisfied internally, and there is no resulting external magnetism. When the steel bar is stroked with a magnet, or placed in a current-carrying coil of wire, the particles rearrange themselves according to the law of attraction, symmetrically with the axis of the coil, thus breaking up the closed magnetic circuit, and so making evident external magnetism.

EXPERIMENTAL PROOF OF THE MOLECULAR THEORY OF MAGNETISM.—Fill a small glass test tube with coarse steel filings and insert a cork in the mouth of the tube. Test each end separately for magnetism by bringing it near a suspended needle. Either end attracts the same pole of the needle, proving thereby that it is not magnetized. Treat the tube now as a steel bar, and being careful not to shake it, proceed to magnetize it by any of the methods previously given. Test again with the needle; one end repels one of the needle's poles and attracts the other pole. Always make a repulsion test to prove that a body is a magnet. Now shake the tube thoroughly so as to intermingle the filings, repeat the tests above, and you will find that the tube is no longer a magnet, but has been demagnetized. The filings are now indiscriminately arranged in the tube with the magnetic circuit of the numerous small magnets completed through each other, hence no external magnetism. When rearranged in the tube under the influence of magnetic force, they assume symmetrical positions, each

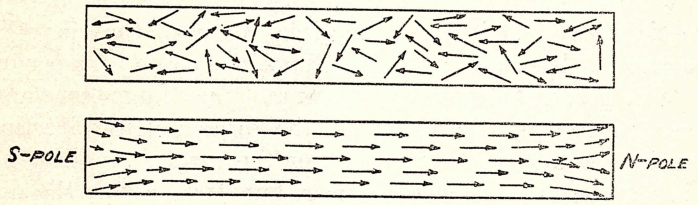


FIG. 2.

one lying in line with, or parallel to its neighbor; N pole next to S pole, and so on. The result of this rearrangement of a number of small magnets would be an accumulation of the lines of force, which, when they reached the end of the tube, would have no other path to complete their circuit; so that the tube presents the characteristics of a bar magnet. Fine particles of magnetic oxide of iron (loadstone) mixed with water may be poured into a tube. When the tube is shaken it is impervious to light, because of the satisfied internal arrangement of the magnetic circuits; when placed in a coil of wire carrying a current the particles rearrange themselves longitudinally so that when viewed from the end of the tube they offer less obstruction to the light.

BREAKING A MAGNET.—The breaking of a magnet further supports the molecular theory of magnetism. Magnetize a long, thin piece of hard-tempered steel and mark the N pole. Break it in half and test each piece separately. In one half the N pole remains N, as previously marked, but a new S pole is developed, while in the other piece the S pole remains as before and a new N pole is developed. Break these pieces again and each part is a perfect magnet with the poles distributed as in the previous case. Break the re-

maining pieces until they become too small to be broken, testing each one, and every one is still a magnet. The conclusion is, then, that a steel or iron magnet is an aggregation of small magnets, arranged in a magnified position.

MAGNETIC SATURATION.—We can not see the molecules of iron or steel changing their relative positions under the influence of magnetism, but these experiments are intended to show what probably takes place when steel or iron is magnetized. According to the theory, the magnetized iron or steel has its molecules irregularly disposed, as the steel filings were in the tube when shaken. Magnetization turns them around on their axis until they are arranged symmetrically. When they have all been turned around, the bar is said to be saturated or completely magnetized; it can not be further influenced by magnetism, however strong the force.

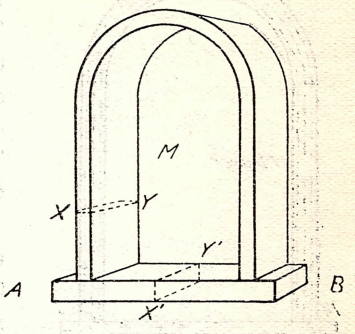


FIG. 3.

THE WEAKENING OF PERMANENT MAGNETS.—A permanent magnet will grow weaker with time. It is not as permanent as the term assigned to it implies. It, however, may be so treated that a rapid loss of magnetism will occur in a very short time. Any action tending to give more freedom of motion to the minute particles composing it, will cause these particles to revert to their mixed state prior to the magnetizing of the bar.

KEEPERS.—A keeper is a piece of soft iron placed across the poles to connect them. Its function is to provide a complete short circuit, or closed path for the magnetic lines between two unlike poles. The magnetism induced in the keeper reacts on the magnet, and not only helps to maintain the strength of the magnet but also serves to augment it. A magnet deprived of its keeper gradually loses its magnetism. Steel is much more readily demagnetized than magnetized, so that magnets require careful handling when in use and should be provided with keepers when put away. A magnet should never be removed from a magneto unless it is immediately placed upon a keeper. Two horseshoe magnets may be arranged to keep themselves if the poles are properly determined. Otherwise more injury than good will be done.

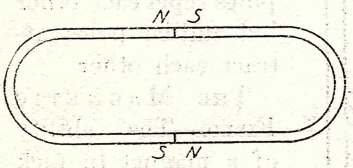


FIG. 4.

THE POLES OF A MAGNET.—We have had occasion to mention the poles of a magnet. This was done by assuming that the meaning of

"poles" could be obtained by inference. However, the application of the term "pole" can be better implied by observing the following experiment: Take a magneto magnet and roll it around in a pile of iron filings. The filings will adhere in certain spots; these spots or portions of the magnet are called poles. They are located at the two ends of the bar, forming the magnet. The section between the poles is called the neutral zone.

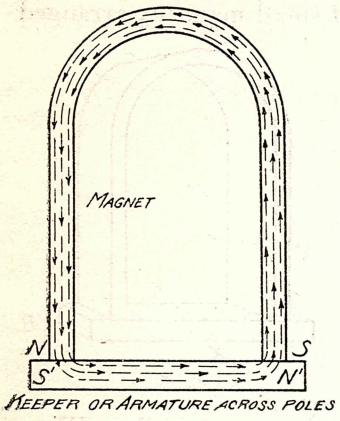


FIG. 5.

THE POLES.—The ends of a magnet are termed its poles. The end which points toward the north geographical pole is generally called the north pole and is usually marked on the end of the magnet by an "N" or a line cut in the steel, while the other unmarked end is the "S" pole. By the term "polarity" we mean the nature of the magnetism at a particular point; that is, whether it is north or south seeking magnetism.

MAGNETIC ATTRACTION AND REPULSION.—If we should suspend a bar magnet in a stirrup, ascertain and mark its N pole and then bring near it the N seeking pole of another bar magnet held in your hand, the N pole of the suspended magnet is repelled by the N pole of the magnet held in your hand, while the S pole of the suspended magnet is attracted by this same N end. In a similar manner it will be found that the two S poles repel each other, while either S pole attracts the unlike or N pole. Thus: Like poles repel each other but unlike poles attract each other.

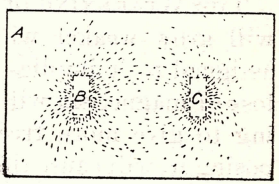


FIG. 6.

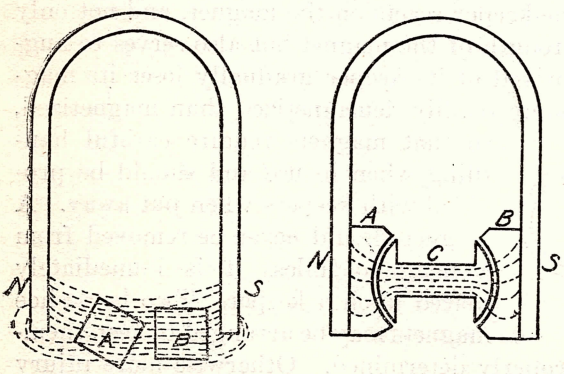


FIG. 7.

THE MAGNETIC FIELD.—The ability of a magnet to pick up iron filings or pieces of iron or steel is conceived to be due to a flow of invisible "lines of force." Each line is a complete loop, starting anywhere within the magnet, out the N pole end, across

the air gap or any suitable conductor between the poles, and in the S pole end. There is a countless number of these lines; more in the case of a strong magnet, and less in the case of a weak one. When given their full name they are called magnetic lines of force.

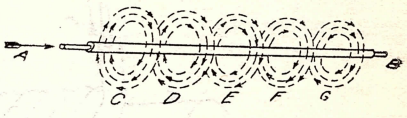


FIG. 8.

A magnetic field may be defined for our present purpose as the space between the poles of a magnet through which a fairly concentrated number of magnetic lines of force are passing. A very good idea of a magnetic field may be had by noting the formation of iron filings within such a field as per the following experiment:

Experiment.—Secure a piece of cardboard, 8 by 12 inches, some clean iron filings and a good strong magnet. Sprinkle a few of the filings evenly on the cardboard, particles not closer than one thirty-second of an inch. Place the cardboard carefully over the poles of the magnet and tap it gently with a pencil; the filings will assume lines whose plan of formation will be that of the magnetic lines of force.

THE ELECTROMAGNETIC FIELD.—Electricity and magnetism are so closely related and so mutually dependent upon each other in their use and practical application to the performance of work, that their interactivity must be carefully considered. The results of electromagnetic activity are known as "induction."

When an electric current flows through a conductor a magnetic field is established about the conductor. Experiments tend to show that this field is built up of invisible lines of force existing in rings whose planes are at right angles to the direction of current flow.

ACTION OF LINES OF FORCE.—If an iron or steel bar be placed within this field it will become a magnet and its poles will correspond with the direction of the lines through it. These lines of force are dependent for their direction on the direction of the current flow.

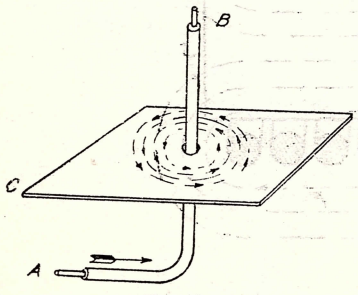


FIG. 9.

AN IRON CORE AND A WINDING.—It has been found that if a carefully insulated wire be wound around an iron bar and an electric current passed through the wire the bar will become strongly magnetic. It is not hard to conceive how this action is accomplished, knowing what we do already about the electrical field lines of force. If the bar be one of malleable iron, the magnetic exhibition will immediately disappear when the current flow is stopped. If the bar be one of a hard, dense steel, the cur-

rent will have to flow longer to gain a noticeable magnetic strength to the bar, but upon the stopping of the current flow the bar will retain much of the magnetism and become a permanent magnet.

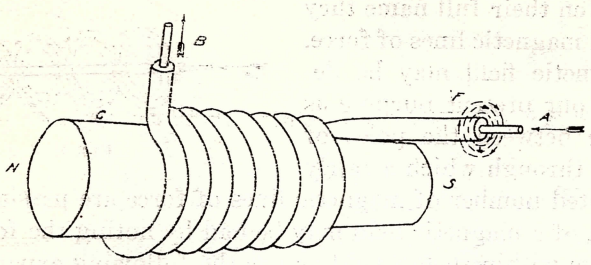


FIG. 10.

FIELD INTENSITY OF A CORE.—When the wire is wound around the bar (commonly called a core) a great concentration of the lines of force is brought to bear upon the bar. It is like taking a coiled spring and bending it into a circle—the loops of the inner curve are brought very close, but the loops of the outer curve are much separated. Due to the progression of turns down the core bar the lines of force are elongated the length of the bar. Note the figures.

THE PRINCIPLE OF INDUCTION.—So far we have found a number of peculiarly correlated facts; these may be expressed as follows:

(1) Magnetism gives rise to magnetic lines of force.

(2) Magnetic lines of force produce a magnetic field.

(3) An electric current gives rise to magnetic lines of force.

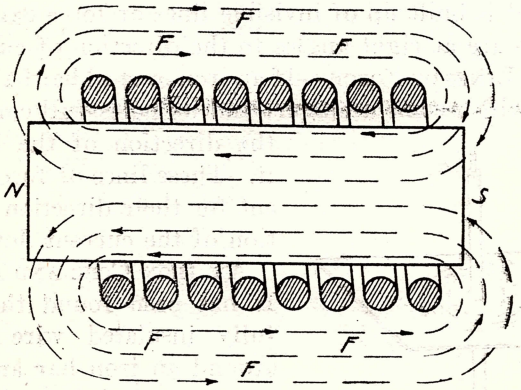


FIG. 11.

(4) These lines of force form what is known as the electromagnetic field.

(5) As far as practical results are concerned magnetic fields, whether set up by permanent magnets or by the flow of current

through a conductor, produce the same result, namely, in one instance the magnetization of an iron bar.

EXPERIMENTS IN INDUCTION.—We can at least reason that if by the passage of an electric current through a coil wound about a bar we are enabled to make the bar magnetic then what would happen if we abruptly magnetized a bar from outside source about which was wound a coil forming part of a circuit? This is exactly what an early electrician, Faraday, asked himself, and the following is how he found the answer:

In operation this apparatus was found to work thus: Upon passing a current from D to E through the winding about C, C became magnetic with its

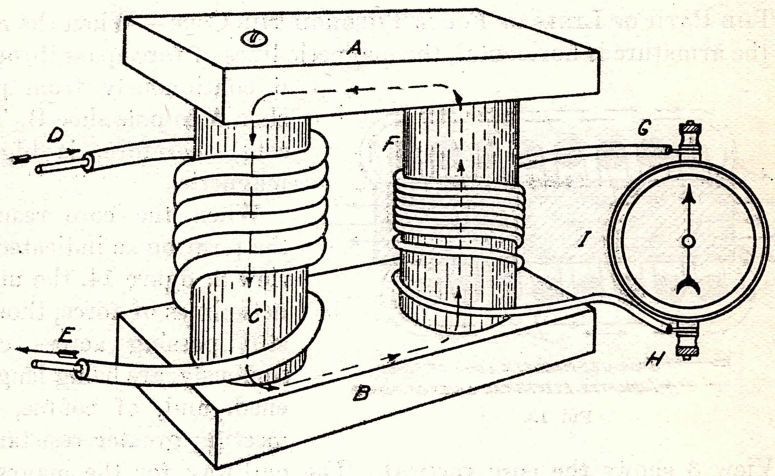


FIG. 12.

N pole at the bottom and its S pole at the top, thus creating magnetic lines of force as per the arrows in the figure.

When the magnetic lines of force pass through F, F becomes magnetic.

During the brief period that F is magnetizing, the indicator I shows a current through the winding about F in the direction of H to G. This current flow immediately ceases when F stops increasing its magnetic intensity.

When the current is cut off from the winding about C, C demagnetizes and, of course, so does F.

During the period that F is losing its magnetism a current is again indicated in the winding about F by the indicator I, but this time in the direction of G to H.

If the current in the winding about C is reversed in direction, then all the incidents related above occur in the opposite direction.

If the current is allowed to flow through the winding about C in the direction as indicated in the figure continuously and F with its winding is slid out from between blocks A and B and reversed end for end, being immediately slid back, a great change will be noted in the indicator at I. It will show a stronger current flow from the period of change than at any time previous, incidentally in the direction of H to G. Each of the steps in the experiment outlined above are based on the fact that when a core with a winding about it is made mag-

netic the magnetic lines of force changing in intensity induce an E. M. F. in the winding. When the magnetic lines of force reach a maximum number, no further change takes place in the field strength, and the E. M. F. ceases to exist. The exact opposite of this action takes place when the core is demagnetized. The collapse of the magnetic field causes an opposite E. M. F. to be induced.

THE POLARITY OF THE ARMATURE CORE AS IT ROTATES.—In applying the information we have gathered in the foregoing to the magnetic armature, it is best that we first treat on the armature core and study out the effect of the magnetic field upon the core when the core is in some of its characteristic positions between the pole shoes. The positions are most readily observed by a series of diagrams such as given below.

THE PATH OF LINES OF FORCE THROUGH THE CORE.—When the core of the armature is horizontal, the magnetic lines of force pass through it continuously from pole shoe A to pole shoe B. The core, therefore, is highly magnetic.

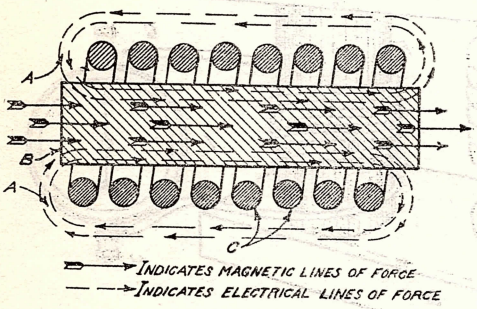
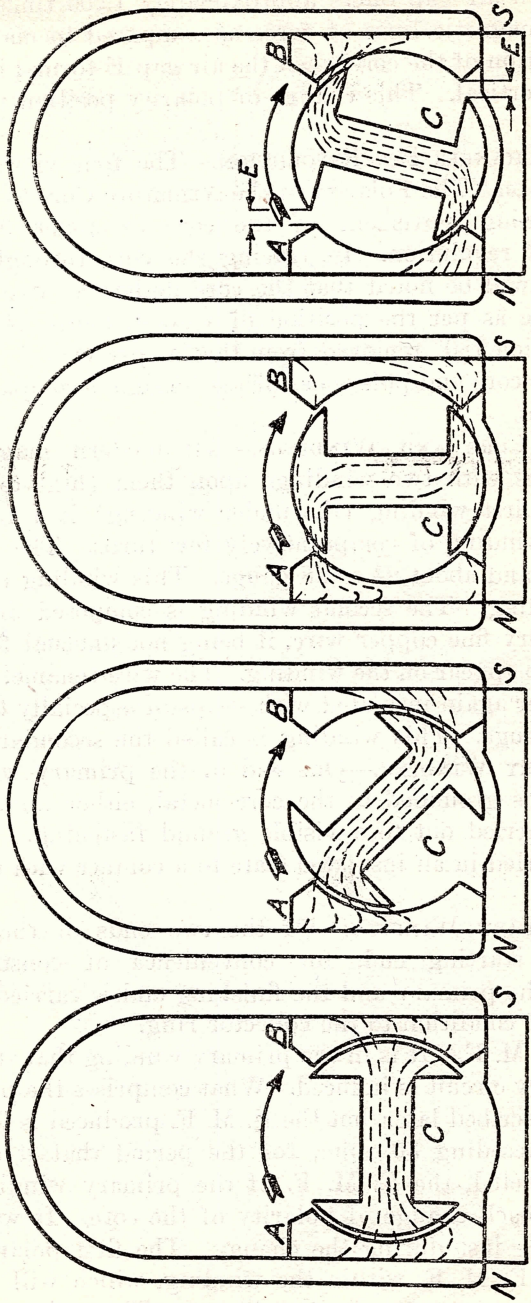


FIG 13.

When the core reaches the position as indicated in view 2, figure 14, the magnetic lines of force, though still passing across continuously, are being lengthened, and, of course, are meeting greater resistance.

View 3 shows the core vertical. The pathway for the magnetic lines of force has been so lengthened that some few lines have left the core and are passing directly across through the core heads. Most of them are still passing through the core, as in view 2, figure 14, due to the fact that any change is resisted, since according to the laws of electromagnetism, any change in the intensity of the magnetic field must result in the induction of E. M. F.'s both in the core and in the windings. As a result, the magnetic lines of force become considerably lengthened or distorted before any considerable change takes place. As the armature turns, the increasing distortion and air gap forces the reversal of the core magnetism, and the core construction is such that this reversal, when it comes, is very rapid owing to the counter magnetic forces brought to bear on it by the stationary pole shoes.

THE REVERSAL OF CORE FLUX.—In view 4, figure 14, a great change has occurred in the magnetic condition of the core over that of view 3. The core has changed polarity. The magnetic lines of force have stopped passing through the core in their former direction and are now passing through in the opposite direction. The design of the core heads and the pole shoes as to shape has permitted of the



View 1. View 2. View 3. View 4.

FIG. 14.

forming of the compound gap E with the further turning of the armature. An air gap offers approximately 1,200 times the resistance to the magnetic lines of force as compared to malleable iron. Note the position of the core when the air gap E forms; it is roughly 20° beyond vertical. This change of polarity position is important to remember.

Polarity Changes Per Revolution.—The four views, figure 14, of paragraph on "The Polarity of the Armature Core as it Rotates," shows a turning movement of the core of about 90°, or less than one-half revolution. In tracing the core through an entire revolution it will be noted that the core undergoes two changes of polarity—once as per the position of view 4, figure 14, and again as per a position 180° removed from that as per view 4. As will be seen later, the core and pole shoes of this design accompany the two-spark magneto.

Armature Core and Windings.—All modern magnetos have armature cores with two windings upon them (high-tension magnetos). The first winding (the under winding) is a fairly coarse copper wire winding of comparatively few turns. The wire is cotton insulated and about 24 to 28 gauge. This winding is called the primary winding. The second winding is composed of thousands of turns of very fine copper wire, it being not unusual for nearly a mile of wire to appear on the winding. The wire (enamel insulated), with each layer again insulated with strips of especially treated silk, is about 40 gauge. This winding is called the secondary winding.

The Primary Winding.—One end of the primary winding, the starting end, is grounded to the core metal, either underneath the winding or carried out to a visible ground fastening. The finishing end is carried in an insulated state to a contact with the breaker box parts.

The Secondary Winding.—Of the two ends of the secondary winding the starting end, for convenience of construction, is grounded to the primary and the finishing end is carried in a carefully insulated condition to the collector ring.

Primary E. M. F.—It is in the primary winding that the E. M. F. for the primary circuit is induced. What comprises the primary circuit will be described later, but the E. M. F. produced is low in pressure, never exceeding 30 volts, for the period that it exists. As might be deducted, the E. M. F. of the primary winding will be induced with each change of polarity of the core. It will last but a brief period—just during the change. The first polarity change will cause an E. M. F. within the winding, which will be directly opposite to the second polarity change. The primary current, therefore, induced on one-half turn of the armature will flow through

the primary circuit opposite to the current induced on the second one-half turn of armature.

SECONDARY E. M. F.—It is in the secondary winding that the E. M. F. for the secondary circuit is induced. Though the acquiring of this E. M. F. is very similar to the method employed with the primary, still it is enough different to be slightly confusing if the student were left to deduct one process from the other. When the primary current flow comes into existence, it will use the armature core on the principle of an electromagnet. That is, the core will serve a mutual purpose; first, for the magnetic lines of force arising from the permanent magnets; second, for the magnetic field arising from the primary winding, for the primary current will build up quite an "electromagnetic field," as the electrician prefers to call it. The secondary winding being wound about the primary is well within a large part of the field. Now, any disturbance of this electromagnetic field, increasing or decreasing the number of lines in it, will have its electrical effect upon the secondary winding just as changing the polarity of the core affected the primary winding. Wheat really happens is this: The electromagnetic field is allowed to build up to its greatest intensity (a point where the primary current is strongest), and then the primary current flow is stopped, abruptly dropping the field. The destruction of the field, withdrawing the lines of force, induces a very great E. M. F. within the secondary winding on account of the huge number of turns. The pressure is very high, sometimes reaching 20,000 volts. The E. M. F., like that of the primary, will last just during the time of the field destruction.

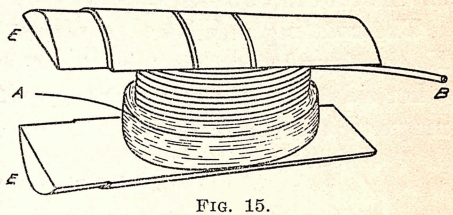


FIG. 15.

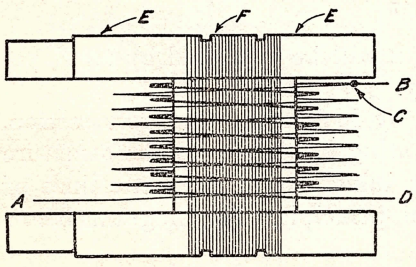


FIG. 16.

PRIMARY AND SECONDARY ALTERATIONS.—Since the primary current changes its direction of flow each current period, then the induced secondary current will also change its direction of flow each current period.

THE SHUTTLE ARMATURE.—The type of armature described in the foregoing is what we call the "Shuttle Armature." It is found in the following common models: Eisemann, type G4–11; Bosch, American-built type; and Berling, types D–41, D–61, and D–81.

THE DIXIE ARMATURE.—The Dixie magneto has a very distinctive type of armature. The armature core with its two windings is stationary and situated above the rotating members under the arch of the permanent magnets, the core of the armature being magnetized and demagnetized by a unique method of rotating the pole shoes between two field pieces. (Note the following diagram.)

The rotating members are so built up that the two shafts H and K, the four lobes 1, 2, 3, and 4 (lobe 2 is not visible, being on the other side), and the two disks I and J rotate as a unit. All parts are magnetic materials except, of course, the brass center G. The four

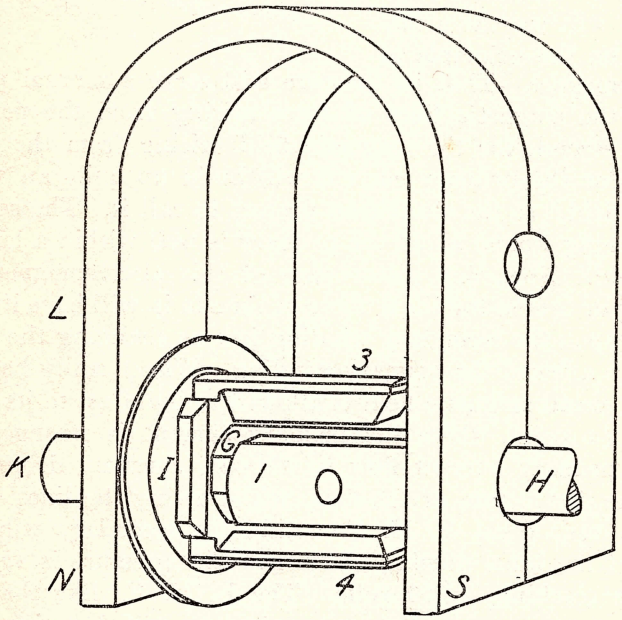


FIG. 17.

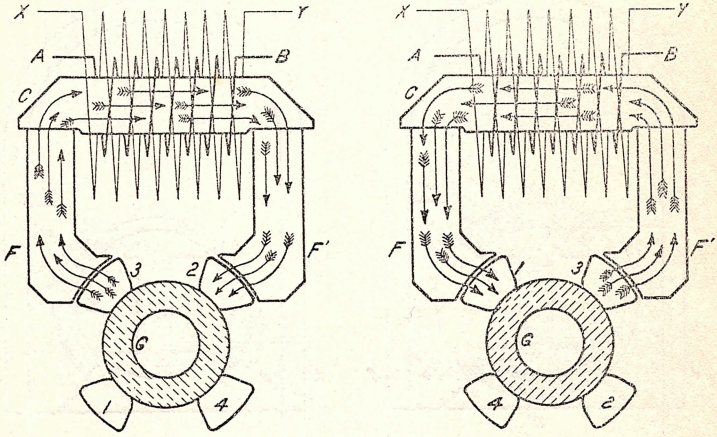
lobes are exactly 90° apart; 1 and 2 will be expressed by an N polarity, and 3 and 4 by an S polarity.

PRINCIPLE OF THE DIXIE.—Now by looking at the cross section, through the very center of the rotating members and the armature assembly we can explain the route taken by the magnetic lines of force and the action of the induction principle. The diagrams below show two views.

Let us observe view 1 first. Remember that lobes 3 and 4 are directly magnetized by the N pole of the permanent magnets, while lobes 1 and 2 are directly magnetized by the S pole of the same magnets. Now F, C, and F′ form a malleable iron conductor for the magnetic lines of force from 3 around to 2, thus linking the two main poles of the permanent magnets. The core of the stationary

armature C is therefore made magnetic with its N pole to the right. Next let us pass to view 2. This figure differs from the other in that the rotating members have moved one-fourth turn clockwise. Such a movement has replaced the lobes in the following manner: No. 2 moved from under F′, No. 3 moved in place of No. 2, and No. 1 in place of No. 3. This action reverses the polarity in F, C, and F′. The core C now has its N pole to the left.

The Special Case of the S. E. V. Bosch.—The S. E. V. Bosch, a European type magneto, differs from the average or common American type in that it is a four-spark magneto. Since it is still found in service we will show a diagram of its operation. This four-spark principle has for its foundation a stationary armature with



View 1. Fig. 18. View 2.

the usual two windings about its armature core. Surrounding the core is what we shall term a "rotating field breaker." It travels in a space allotted to it between the stationary core and the pole shoes of the main permanent magnets. Note the figures below.

The unique feature of this magneto is that due to the drive of the field breaker sleeve, the high tension current as well as the primary must be taken off the armature opposite to the drive end. This fact destroys the possibility of placing the breaker box in the usual position; instead it is put at the drive end of the magneto on the high tension distributor shaft, the shaft running the length of the magneto and operating both the breaker box and the high tension distributor.

Magneto Breaker Boxes.—The function of the breaker box is of the double nature. It must break the primary circuit when the primary current flow is near a maximum, and it must accomplish the break at the proper time with reference to the engine cycle.

Following immediately on the heels of the primary current break comes the secondary impulse, which, upon traveling its circuit, ignites a gas charge in some one engine cylinder. Hence the necessity of accurately timing with the motor the primary current break.

Practically all breaker boxes are identical in principle in their method of opening the primary circuit. The method consists of the mechanical separation of two platinum-tipped contacts, which upon being struck apart by cam action, open the circuit. Because most breaker box parts are small and require nice mechanical adjustments, trouble with this class of unit is more likely to be mechanical rather than electrical in nature. The engine mechanic, familiar with the handling of larger and heavier parts, is very likely to mistreat the

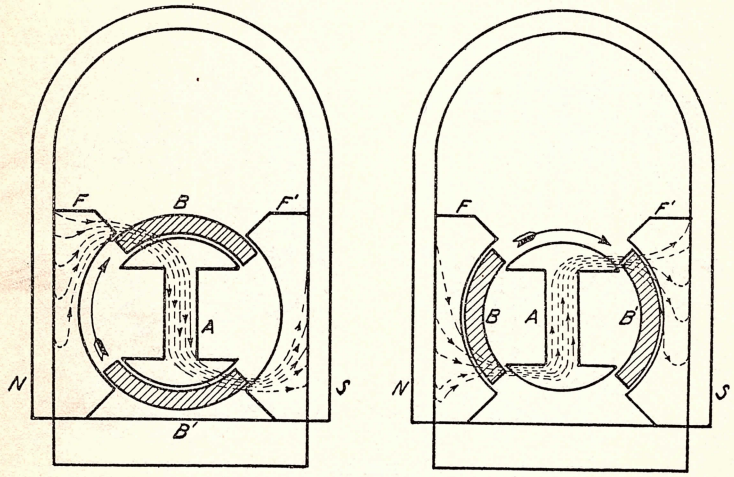


FIG. 19.

breaker box. It is difficult to have him realize the accuracy and nicety of each little adjustment and then have him perform it with the proper tools.

The breaker boxes of the Bosch and Eisemann magnetos are very similar, both having set cams or cam blocks secured to the inner side of a ring-like wall, termed the "breaker-box housing." A rotating assembly of parts rotates with the armature at the center of the breaker-box housing, and a protruding end of the "breaker arm" strikes the cam blocks, breaking apart the platinum contacts. The breaker-box housing can be moved a limited amount in a rotary order upon the mounting on the breaker end plate of the magneto, thus "timing" the engagement of the breaker arm with the cam blocks for "earlier" or "later" spark. The figure gives the details of the Bosch breaker box.

BREAKER BOX CONSTRUCTION.—The action of the breaker box is very simple. The current leaves the primary winding passing to a

contact with the screw A, which is insulated from the ground metal but having electrical contact with B. The block B is also insulated from the ground metal by several sheets of mica under it. Mounted in this block is the platinum tipped contact screw C, which is adjustable and provided with a lock nut. The current, therefore, reaches C still ungrounded, passes to C′, provided the two contacts are together, and then on to breaker arm D. Now, the breaker arm has a grounding spring E, and in consequence, the current becomes grounded at or through E. The holding post of E is part of the assembly disk F, which, of course, is in metallic contact with the armature shaft; thereupon the current flows back to the armature core metal to the point where the end of the primary winding is grounded to it. Thus we note that we have a complete metallic circuit until the fiber rubbing block secured to the end of the breaker

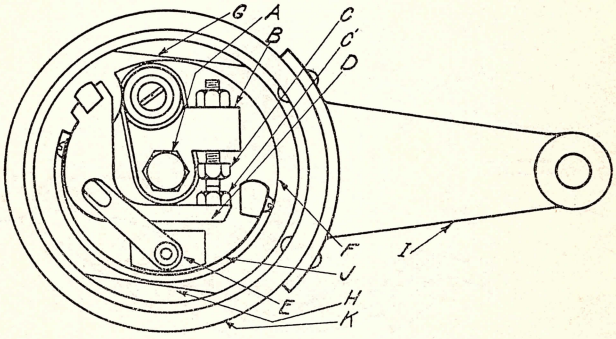


FIG. 20.

arm D, strikes one of the cam blocks, as G or H, with the result that C and C′ are instantly separated and the circuit broken. The separation of C and C′ occurs approximately at the "E-gap" of the armature.

ADVANCE AND RETARD.—The breaker box housing K can be partially rotated upon its mounting to the end plate of the magneto, approximately 25° to 30°, through the use of the control arm I. Suppose that the assembly disks F is rotating clockwise, then a slight movement of I with K in the same direction will cause a "later" contact between the end of D and G, or H. On the other hand, a movement of I and K slightly counterclockwise will cause an "earlier" contact.

THE DIXIE BREAKER BOX.—On the Dixie magneto the cam rotates while the assembly disk remains stationary, a reverse of the mechanical construction on the Bosch.

SOME OF THE COMMON TROUBLES OF THE BREAKER BOX.—Breaker-box failures are largely due to careless mechanic attentions, and often to the use of improper tools. The breaker box with its many small

parts and screws requires special small tools and wrenches for performing the various adjustments it may require from time to time. Too often the mechanic is tempted to use pliers and screw driver for breaker-box repairs, with the result that the damage he does leads to many chance breakdowns. The following list includes some of the common troubles to be guarded against:

Excessive Oil.—Largely the result of the improper oiling of the breaker end bearing of the armature. If this bearing is flooded, instead of a drop or two every three flying hours, the excess oil finds its way into the breaker box and interferes with the correct operation of the contacts therein.

Seizing of the Breaker Arm Fulcrum Pin Bushing.—The breaker arm is usually bushed where it pivots on the fulcrum pin, and this bushing is commonly fiber. Fiber swells when oiled, caus-

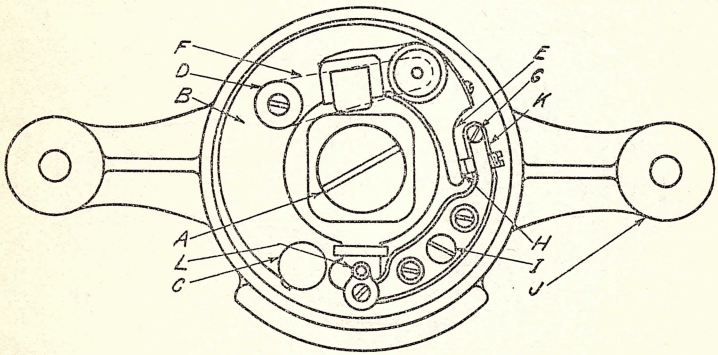


Fig. 21.

ing the bushing to seize the pin. Therefore these fiber bushings must be kept free of oil. Again, the construction may be such that the bushing is not fiber and will seize for want of oil. All the oil this latter type of bushing should receive would be that applied by the moistened end of a toothpick upon the assembly of the breaker-box parts and not regularly. Care must be taken not to wash this part with gasoline and assemble it wet.

Dirty Platinum Contact Points.—Due to oil, the burning of impure platinum particles themselves, dirt, or other foreign matter, the contact points become blackened over and will refuse to make proper contact. A careful inspection of the points will immediately show the extent of discoloration. Should they be rough or discolored they should be cleaned by slightly and evenly filing off with a special fine magneto file that has not been used for any other purpose. Care is to be used to see that the contact is a good contact of area. It is not necessary to file out all the "pits" in the platinum in case they are very deep, just enough so that the area of con-

tact is secured. Very slightly bevel the circular edge of the newly filed surface of each point to remove rough edges due to filing. Make sure that points are firmly mounted and washed clean of filings. Don't assemble while wet with gasoline. Check alignment, test lock nuts, and try breaker arm for looseness on fulcrum, as it will affect alignment of points. Remember that filing points changes the gap at separation and mistimes the separation, and that, if the adjusting point be screwed closer and not be filed off squarely the area of contact will be destroyed. Don't attempt to use platinum points that have been filed off an appreciable amount; place new ones, as the root of many points are made of an alloy which will burn under the electric arc so frequently occurring between them.

Pitted Platinum Points.—It will often be noticed that some grades of platinum will pit very rapidly in service. This is due to the "arcing" between the points, the arc having a mechanical effect as well as very high temperature. The mechanical effect consists of the removal of a minute piece of platinum from one point and electrically welding it to the other. This continued action gives the points a rough gray appearance and they must be filed as prescribed above. Cheap platinum alloys as contact point substitutes, pure platinum which is soft when not alloyed with iridium, points filed down to baser root metals, etc., are all causes for excessive pitting. A broken down condenser will give a combination effect of more arcing, pitting, and burning of the contacts together with a weak "secondary spark."

Note Proper Setting of Platinum Points.—Each magneto is so designed that a carefully measured distance is required for the platinum point separation which is individual with each particular magneto. The distance is required to overcome the arc and properly "time" the points. It is the maximum distance the points separate when the breaker arm engages a cam rise or cam block and is measured with a thickness gauge for each contact.

Eisemann: 0.012 to 0.014 inch.
Bosch: 0.014 to 0.016 inch. (Approximately 0.4 mm.)
Dixie: 0.019 to 0.021 inch.
Berling: 0.016 to 0.020 inch.

Worn Cam Blocks or Cam Rises.—A very little wear of a cam rise or the surface of a cam block will mistime the opening of the contact points as well as lessen the amount of the opening compared to that effected by other cam rises or blocks diametrically situated. This wear is best detected by noting the unequal separation.

Weak Springs.—Particular care should be observed to see that the breaker arm spring has sufficient tension to return the arm promptly to contact position at high speeds. The breaker arm grounding spring should have good firm bearing against the top of

the breaker arm fulcrum. The ground wire binding post contact spring should also have good bearing on the head of the primary contact screw as well as be carefully inspected as to the exactness of its insulation. The breaker box cover spring must bear particularly firmly against the cover, so that the cover can by "no hook nor crook" disengage itself when the breaker box is advanced and retarded. If the cover does fall off, there is nothing to prevent the dropping away of the beaker box housing from the end plate of the magneto.

Breaker Assembly Disk Loose.—Carelessness in replacing the breaker assembly disk may jam it upon the keyway of the breaker end armature shaft, and the first tightening of the primary contact screw will not draw the assembly tight to the shaft with the final result that it works loose. This may interfere with the primary contact as well as make the timing of the platinum contacts uncertain. The same result is obtained with a loose breaker end plate or breaker end armature bearing.

Control Rods to Control Lever Not Correctly Adjusted.—The misassembly of the advance and retard control rods is easily made, as the threaded joints can be readily turned on to the rods too far or not far enough, thus linking up an arrangement that does not move the breaker box housing the full distance each way. This defect of assembly may be so bad that the operator in attempting to make an advance or retard may strain the breaker box housing out of position. When more than one magneto is present on a motor the rods must be carefully adjusted so that the breaker box contacts are strictly synchronical.

Improperly Washing Breaker Box Parts With Gasoline.—When the breaker box is found accidentally flooded with oil, there is a strong tendency on the part of the average mechanic to attempt washing it out with gasoline and a brush without disassembly. Or again, in making haste on the assembly, the parts are put together while still wet with gasoline. If either case becomes an actual happening, there is every possible danger that some part of the numerous small parts will seize or cut in service. The gasoline destroys all chances of an oil film, for the minute quantity of oil that should be added, and leaves all steel parts in condition to readily corrode. This they sometimes will do with startling rapidity.

The Condenser.—The function of the condenser is to prevent arcing at the platinum contact points and to make possible a quicker stop of the primary current flow by aiding electrically the mechanical action present in the breaker box when the platinum contact points separate. We speak of "a stop of the primary current flow" for simplicity, for, as has already been stated, the whole object in "breaking" the primary circuit abruptly is to instantly, if possible,

demagnetize the electromagnetic field about the secondary winding. The quicker the breakdown of this field, the stronger the inductive effect upon the secondary winding, and hence the stronger the secondary current E. M. F. To have the platinum points separate is not destroying the electromagnetic field existing about the conductor of the primary circuit, and, strange as it may seem, this electric field has the property of attempting to reestablish a pressure great enough to overcome the large resistance introduced by the separation of the platinum points. As it is, a certain amount of "self-induced current" will flow the round of the primary circuit for an instant after the platinum points separate, leaping the widening gap between the points in the form of an arc. This "self-induced current," as it is commonly called, results from the collapse of the magnetic field and tends to cause a "carry-on" condition of the former primary current, thus preventing its abrupt stop as might be supposed by the mechanical separation of the platinum points.

Condenser Construction.—The construction of a condenser is comparatively simple, its successful action depending more on the materials selected than the exacting nature of workmanship. It consists of alternate sheets of thin metal and sheets of insulating material called a "dielectric." Its action may be said to depend upon, first, the area of the metal part; second, the thinness of the dielectric; and, third, the kind of dielectric. Thin sheets of mica have been found to form the best dielectric, though thin paraffin paper has been used with considerable success but is used only on account of its cheapness. The kind of metal used is immaterial, so tinfoil forms the sheets of most condensers because of its cheapness, flexibility, and property of being easily formed into thin sheets.

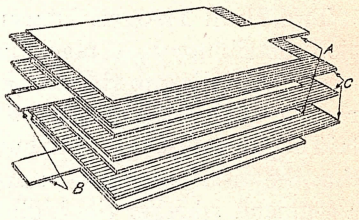


Fig. 22.

A condenser, of course, has a great many more sheets of the dielectric and the foil than the diagram above indicated. Each alternate sheet of tin foil is in metallic contact at one end of the condenser and each other alternate sheet is in contact at the opposite end. The condenser has, therefore, two main contacts; no metallic connection between them, and in consequence no electric circuit between them.

Charging a Condenser.—A condenser has the electrical ability to receive a "charge" depending upon its size. This ability to receive an electrical charge is termed the "capacity" property of the condenser. The condenser does not necessarily need to be charged to its fullest capacity.

FUNCTIONS OF THE CONDENSER.—When the platinum contact points of the magneto breaker box separate, the condenser is connected with the primary circuit, i. e., one contact of the condenser in circuit with one platinum point and the other side with the other, that any current flow attempting "to carry on" will be received by the condenser as a charge rather than complete the circuit by arcing the gap between the platinum points. This charge so received by the condenser will be immediately given backward into the circuit, thus aiding in destroying the electrical field of the primary circuit.

Every time the condenser receives a charge it heats it somewhat, and, if the dielectric is paraffin paper it may break down under the strain of the repeated charging. Such a breakdown is noticed by excessive arcing at the platinum points and a weaker secondary current. In time, following a breakdown, the condenser might actually short the primary circuit around the points. A mica condenser rarely gives the breakdown troubles above related and lasts almost indefinitely. Most high-grade magnetos are equipped with mica condensers.

THE HIGH-TENSION DISTRIBUTOR.—The function of the high tension distributor is to place into the circuit each spark plug upon the motor according to the firing order. To make this possible it should revolve at the rate of one-half the speed of the crank shaft. The inlaid segments of the distributor block must be made wide enough so that the distributor rotor can be timed and always be in contact with a segment, whether the high tension current impulse comes "early" or "late." The "early" and "late" having reference to the advance and retard of the breaker box and the subsequent action upon the secondary circuit.

In checking the timing of the high-tension distributor, care is to be exercised to see that the distributor rotor is just entering a segment for "early" setting of breaker box, and not over two-thirds way across for "late" setting of breaker box. If the high-tension distributor should by accident be timed so that the distributor rotor was off a segment when the current impulse arrived, the current would jump to the nearest segment and burn the face of the distributor. Any irregularity on the face of the distributor, or the failure of the distributor brush to bear squarely and firmly in traveling over the face, will cause arcing at this point and the consequent injury of the parts.

THE COMPLETE SECONDARY CIRCUIT.—On the average magneto the secondary circuit may be traced as follows: Starting with the secondary winding, the current may leave the winding in either direction, i. e., depending on the order of induction, it may lead off to the grounded end or to the collector ring; but let us presume that its E. M. F. is impressed so that it carries off to the collector ring.

From the collector ring it travels up the collector brush, then to the brush holder, next to the distributor pencil which is in direct contact with the distributor rotor. The distributor rotor with its contact brush should lie on a segment if the magneto is correctly timed; therefore the current would pass to the segment in question and out along the spark plug cable in contact, down the central electrode of the plug, across the air gap, and on to the grounded electrode, over the ground metal to the magneto ground metal, and up to the carbon grounding brush, which is usually mounted on the back of the breaker box assembly disk. (The Dixie magneto requires no ground-

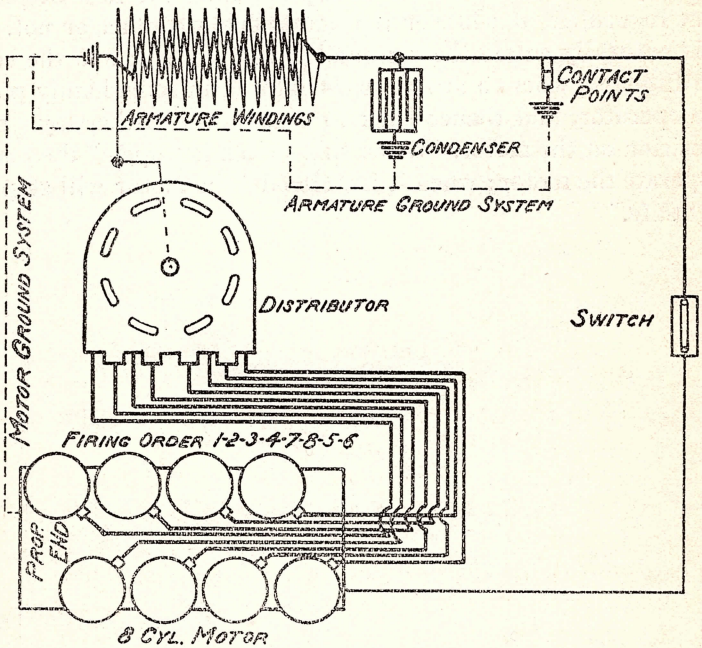


FIG. 23.

ing brush for the high tension current. Why?) Thence it passes over the armature ground metal to the grounded end of the primary winding through the primary system to the attachment of the grounded end of the secondary winding with it, and thence home again to the secondary winding where we started. Bear in mind that this circuit may be traced in either direction, also that the current E. M. F. may originate in the winding, giving a current flow in either direction with practically equal results at the spark plug.

THE PRIMARY CIRCUIT OUTSIDE THE MAGNETO.—The primary circuit in the ordinary course of events does not leave the magneto. This fact has already been brought out. Arrangements, however, must be made to "switch off" the ignition current in order to stop

the engine. The ignition current is the secondary current, and the secondary current may be stopped by stopping its induction. This latter act may be accomplished by not interrupting the primary flow. In order that the primary current flow may not be interrupted by the breaker points in the breaker box a current must be provided around them. It is customary to do this by providing in the cover of the breaker box a contact with the primary contact screw of the assembly disk. This contract finds expression on the outside of the cover in the form of a binding post. A wire running from this binding post and grounded will continue the primary circuit around the platinum points of the breaker box, permitting the flow of primary current regardless of whether the points break contact or not. This wire is naturally called the "ground wire." It is led to the cockpit of the fuselage, where a switch is introduced in some handy position to the operator, and thence back to a good out-of-the-way grounding position on the motor. When this switch is "open" the magneto will operate the motor; when it is "closed" the motor will stop or be made "safe."